Title: Deep Space Navigation Automation and Autonomy: A Technical and Cost Survey

Topic: Operations Automation

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ABSTRACT

The navigation of deep space spacecraft, a practice which has now enterered its fourth decade, is undergoing rapid changes due to increasing cost pressure and new capabilities enabled by the revolution in information processing techniques and hardware. Whereas in t-he past the only option for the navigation of such missions was the use of high performance computation systems and the analysis skills of a large team of dedicated personnel in processing radio tracking data received at large dedicated ground stations, a large number of options now exist. This paper undertakes-an overview of' the current best practice and expected near term devel opments in a number of these systems from both a capabi lity and cost. perspective .

Traditional Ground Based Radio Navigation

The traditional way of performing the navigation of deep space vehicles, ground based radio navigation, has undergone recent improvements which has greatly decreased the operations costs associated with this technique.

Ground Automation of Radio Navigation

Improved systems are now capable of performing the ground hased navigation of many missions in a totally (or nearly totally) automated fashion. This will allow for the automated processing of radio data received from NASA's Deep Space Network (DSN) at a tiny fraction of previous operations costs.

On-board Processing of Radio Metric Data

The processing of a radio signal received on-board a spacecraft is well within the hardware and software capabilities now extant and is a direct outgrowth of ground automation.

Optical Navigation, the past and current state

JPL has been performing optical navigation operationally since 19"/8 with the Voyager J encounter with Jupiter. The OPNAV system and process for Voyager Jupiter were very manually intensive, requiring several dozen steps and programs. Throughout. the 10-year Voyager mission, the operational procedures and software were upgraded and streamlined, allowing somewhat. lower staffing levels, but nevertheless the system remained basically manual.

Optical Navigation, automation

As in the case of radio navigation, cost pressures are demanding increased efficiency from the OPNAV system, and increased ground and flight computer power are enabling greater automation. For Galileo, a very rudimentary autonomous image analysis capability was necessitated by reduced down] ink capabi l ity and many ground processes have been largely automated. For the Cassini mission, little more than high level occasional monitoring will be required; with significant savings in staffing are expected.

Optical Navigation, Autonomy

The final step in the progression of the OPNAV systems is to a totally

autonomous system. Such a system is required to achieve maximum science return from a deep space mission as round-trip light-time limits the accuracy of a ground-based operations system. Additionally, once an autonomous system is built using an onboard imaging capability, ground operations can be further reduced by eliminating tracking necessitated by navigation. Such an autonomous OPNAV capability is currently under development for the New Millennium Deep-Space-1 Mission, and though initial development costs are high, subsequent operations costs on this and future missions stand to be dramatically reduced.